IN THE UNITED STATES DISTRICT COURT

FOR THE DISTRICT OF DELAWARE

PECHINEY RHENALU,	)	
	)	
Plaintiff,	)	
	)	
v.	)	Civil Action No. 99-301-SLR
	)	
ALCOA INC.,	)	
	)	
Defendant.	)	

Richard L. Horwitz, Esquire of Potter Anderson and Corroon LLP, Wilmington, Delaware. Counsel for Plaintiff. Of Counsel: James R. Atwood, Esquire, William D. Iverson, Esquire and Christopher N. Sipes, Esquire of Covington & Burling, Washington, D.C.

R. Franklin Balotti, Esquire and Frederick L. Cottrell, III, Esquire of Richards, Layton & Finger, Wilmington, Delaware. Counsel for Defendant. Of Counsel: Evan R. Chesler, Esquire and Daniel Slifkin, Esquire of Cravath, Swaine & Moore, New York, New York.

OPINION

Dated: September 19, 2002
Wilmington, Delaware

ROBINSON, Chief Judge

I. INTRODUCTION

Plaintiff Pechiney Rhenalu ("Pechiney") filed this action against defendant Alcoa, Inc. ("Alcoa") on May 12, 1999, seeking a declaratory judgment that its 2024A aluminum alloy product ("2024A alloy") does not infringe Alcoa's United States Patent No. 5,213,639 (the "'639 patent") and that the '639 patent is invalid, as well as seeking damages for Alcoa's alleged tortious interference with Pechiney's prospective business relations.[1] (D.I. 1) On February 29, 2000, Alcoa filed a counterclaim asserting that the 2024A alloy infringes the '639 patent. (D.I. 174) Pechiney filed an amended complaint in March 2000 adding a claim of inequitable conduct. (D.I. 175) The parties later stipulated that they "withdraw with prejudice their pending requests for monetary relief, and further agree that no monetary relief (including damages) will be sought in this litigation." (D.I. 245)

Following discovery, Alcoa offered Pechiney a covenant not to sue for infringement of the process, product-by-process, and certain product claims of the '639 patent, consequently, these claims were dismissed from the case. (D.I. 366) On December 22, 2000, the court held that claims 81 and 82 were invalid as to this action due to a typographical error. (D.I. 385)

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[1]On December 14, 2000, the court granted summary judgment in favor of Alcoa on Pechiney's tortious interference claim. (D.I. 373)

From January 8, 2001 through January 18, 2001, the parties tried the issues of validity and infringement to a jury, and the issue of inequitable conduct to the court. During the trial, Alcoa offered Pechiney a covenant not to sue on several additional product claims, which were also dismissed. (D.I. 410) At the close of trial, Alcoa was asserting infringement of sixty product claims of the '639 patent.[2]

On January 18, 2001, the jury returned a verdict that the asserted claims are infringed by the 2024A alloy, not invalid as anticipated under the on-sale bar of 35 U.S.C. § 102(b), and not invalid as obvious under 35 U.S.C. § 103(a). (D.I. 417) On March 29, 2001, the court entered judgment in favor of Alcoa and against Pechiney based on the jury's verdict. (D.I. 455)

On September 28, 2001, following briefing and oral argument on post-trial motions, the court vacated the judgment based on the jury's verdict pursuant to Tegal Corp. v. Tokyo Electron Am., Inc., 257 F.3d 1331 (Fed. Cir. 2001), cert. denied, 122 S.Ct. 1297 (2002), and ordered the parties to file proposed findings of fact and conclusions of law. (D.I. 480)

The court has jurisdiction over this matter pursuant to 28 U.S.C. §§ 1331, 1338(a), 2201 and 2202. The following are the

[2]These claims are: 72, 73, 75, 78, 80, 86, 87, 89, 91, 93, 95, 97, 99, 101, 103, 136, 138, 139, 141-47, 149-57, 159-66, 192-95, 214, 216, 218-23 and 225-30 (the "asserted claims").

court's findings of fact and conclusions of law pursuant to Fed. R. Civ. P. 52(a).

II. FINDINGS OF FACT

A. The Parties

1. Pechiney is a corporation organized and existing under the laws of France and having its principal place of business in Paris, France. Pechiney is a producer of aluminum and aluminum products, including aerospace alloys, which it sells in numerous countries, including the United States. (D.I. 424 at 1814)

2. Alcoa is a corporation organized and existing under the laws of the Commonwealth of Pennsylvania and having its principal place of business in Pittsburgh, Pennsylvania. Alcoa is the world's largest commercial producer of aluminum and aluminum alloys for aerospace applications, which it sells throughout the United States and the world. (Id. at 1814-15)

B. The Field of the Invention

3. Aluminum alloy products have long been used as the primary building material for commercial aircraft because of their strength and damage tolerance in relation to weight. (Id. at 1815)

4. Strength refers to the stress an alloy is able to withstand without breaking. (D.I. 418 at 151-52)

5. Damage tolerance refers to the ability of an alloy to resist failure due to the presence of flaws, cracks or other

damage for a specified period of usage. (D.I. 423 at 1339) Fracture toughness and fatigue crack growth rate are the damage tolerance properties of an alloy. (D.I. 418 at 154-61)

6. Fracture toughness is the measurement of an alloy's ability to resist the extension of a crack, often measured in terms of the stress intensity factor (K) at which applying progressively greater stress to a structure that contains a pre-existing crack causes the onset of rapid catastrophic propagation of that crack. (DX 188, col. 9, lns. 55-58; D.I. 418 at 154) The fracture toughness values reported in the '639 patent are referred to as K_c or K_{app} values and measured in units of ksi/in. (DX 188, cols. 10-11) K_c values are slightly higher than K_{app} values for the same material because K_{app} is based on initial crack strength and final failure stress. (D.I. 418 at 157-58)

7. Fatigue cracks in an airplane fuselage result from cycles of stressing and relaxing, such as the repeated loading and unloading that might occur as a wing moves up and down or a fuselage swells with pressurization and contracts with depressurization. (DX 188, col. 11, lns. 55-60; D.I. 418 at 153) Fatigue crack growth rate is the rate of crack extension caused by these cycles, measured in terms of average crack extension per cycle (da/dN). (DX 188, col. 11, lns. 56-67; D.I. 418 at 160-61) ")K" refers to the difference between the maximum and minimum loads (in ksi/in), and the "R ratio" refers to the ratio of

minimum to maximum load. (D.I. 418 at 162) A "T-L" crack is one that is oriented in the longitudinal direction of the airplane fuselage, and an "L-T" crack is one that is oriented wing to wing across the top of the fuselage.[3] (Id. at 158-160)

8. Damage tolerance in aluminum alloy products is impaired by the presence of undissolved particles, which facilitate crack growth and thereby reduce fracture toughness and increase an alloy's fatigue crack growth rate. Iron (Fe) and Silicon (Si) particles are insoluble in aluminum, and can be reduced or minimized only by using a high-purity base aluminum material with smaller quantities of these impurities. (PX 585A; D.I. 421 at 813-17; D.I. 423 at 1342) Copper (Cu), Magnesium (Mg) and Manganese (Mn) are soluble in aluminum, but only up to a certain point. These particles may be reduced by controlling composition of the alloy so that the particles are limited to amounts that can be dissolved in the aluminum during the production process. (Id.) The soluble particles may also be reduced by using thermal treatments to dissolve them in the aluminum as much as possible. High-temperature heat treatments are desirable for this purpose

[3]"Crackstoppers" are small, thin strips of high-toughness material that are either bonded by adhesive or riveted to aircraft fuselage skin to stop cracks that may initiate and grow within the skin. (D.I. 422 at 1175; D.I. 418 at 170-72) Crackstoppers are effective in arresting fast fracture provided that there does not exist multi-site damage ahead of the lead crack. (D.I. 418 at 189)

because solubility limits are higher at higher temperatures. (PX 585A; D.I. 423 at 1346-47)

9. The typical production process for aluminum alloy products involves several steps. First, the aluminum elements are melted in a furnace and cast into solid ingots which, for aircraft applications, are typically 20 feet long, 14-16 inches thick, and 20,000 pounds in weight. (Id. at 365-67) Next, the ingot is heated in a furnace and, if desired, a layer of cladding is applied.[4] (Id. at 369) Then, the heated ingot is "hot-rolled" to reduce its thickness. (Id. at 370, 380-81) Next, the material is subjected to a solution heat treatment, during which a high temperature is applied for a short time to move the elements within the material to their most beneficial positions. (Id. at 371-72) Finally, the material is "quenched" or rapidly cooled to lock the elements in those positions.[5] (Id. at 372)

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[4]"Cladding" is a layer of pure aluminum placed over an alloy to enhance corrosion resistance, which is the ability of the alloy to resist rust. (D.I. 418 at 164; DX 188, col. 4, lns. 39-42) Cladding generally lowers the yield strength of an alloy because pure aluminum is of lower strength than bare material. (D.I. 424 at 1779-80; D.I. 422 at 1233-34; D.I. 423 at 1360-61) "Cladding diffusion" occurs when some of the elements within an alloy seep into the cladding and change its composition, thereby reducing the corrosion resistance of the alloy. (D.I. 419 at 373, 376) The addition of cladding to an alloy limits the use of long-term high-temperature heat treatments during the fabrication process, which contribute to cladding diffusion. (Id. at 376-77; D.I. 424 at 1729-31; D.I. 423 at 1525)

[5]Heat treatments may be provided during the preheat stage before hot rolling, during intermediate reheating between two hot rollings, or during solution heat treatment after hot rolling.

10. Aluminum alloy products are formed into either "sheet" or "plate." Sheet products have a maximum thickness of 1/4 inches, whereas plate products have a maximum thickness of 5/8 inches. (DX 188, col. 6, lns. 55-58, col. 10, lns. 5-40) Airplane fuselage is made of aluminum sheet. (D.I. 418 at 212)

11. The Aluminum Association in Washington, D.C. has developed an International Alloy Designation System to designate the allowable range of composition of various common aluminum alloys. (D.I. 424 at 1815-16) All "2XXX" series alloys are comprised of wrought aluminum alloys in which the major alloying ingredient is copper. (Id.) The "2X24" or "2024-type" alloys are those with the principal alloying elements being copper, magnesium and manganese, and the Aluminum Association designation has set upper and lower percentage limits for each of these elements. (Id.) Iron and silicon are also present as impurities, and the Aluminum Association designation has set an upper percentage limit for each. (Id.)

12. For at least fifty years, the fuselage skin of many commercial aircraft has been manufactured with clad 2024-T3 alloys. (D.I. 424 at 1815-16; D.I. 418 at 170; D.I. 423 at 1339) "T3" refers to the heat treatment of the alloy. (D.I. 418 at 164)

(D.I. 419 at 272)

C. Development of Alcoa's 2524 Alloy

1. Boeing's Request for a New Alloy

13. Boeing is the only manufacturer of large commercial jet liners in the United States. (Id. at 183)

14. In late 1988, Boeing asked Alcoa to develop an improved aluminum alloy for use as the fuselage skin on the forthcoming new design 777 aircraft.[6] (D.I. 424 at 1816; D.I. 418 at 205; DX 28) Boeing was looking for a material with improved fracture toughness and fatigue crack growth resistance to increase safety and reduce inspections and repair costs. The material had to be as strong and formable[7] as 2024-T3, and resistant to corrosion.

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[6]Boeing's desire for an improved alloy was fueled in part by two aircraft accidents in the 1980s. In August 1985, a Japan Airlines Boeing 747 crashed as the result of multi-site fatigue cracks in the 2024 alloy near the rear pressure bulkhead, which is responsible for maintaining cabin pressure during flight. (D.I. 418 at 166, 175-76) In the spring of 1988, a large section of 2024 fuselage skin ripped off an Aloha Airlines Boeing 737, killing a flight attendant and injuring other passengers. (Id. at 207-08) This incident was also caused by multi-site fatigue cracks that overwhelmed the aircraft's crack arresting system. (Id. at 178-80)

Richard E. Lewis, Pechiney's expert on aircraft design, explained that attempting to "inhibit the crack[s] from growing," and thereby increasing the safety of aircraft, has been a focus of fuselage design since at least the 1950s, when two Comet airplanes crashed due to undetected propagation of fatigue cracks. (D.I. 422 at 1176-78) Pierre Chaumes, a senior executive of Pechiney, also stated that during the 1980s, alloy manufacturers sought higher damage tolerant aluminum alloys to replace 2024 "in order to avoid accidents." (D.I. 424 at 1752)

[7]Formability is the ability of an alloy to be formed into a useful shape without any detrimental effect to its properties. (D.I. 418 at 163)

(DX 28; DX 35; DX 46; D.I. 418 at 208-10, 216, 222-23) Weight savings was also a concern for Boeing.[8] (PX 2319)

15. Alcoa undertook to develop a new aluminum alloy to try to satisfy Boeing's request. (D.I. 424 at 1816) Jocelyn Petit, an Alcoa metallurgist and a named inventor of the '639 patent, was assigned to be initial project leader for the effort. (D.I. 418 at 204)

16. Ms. Petit developed a table of various candidate materials and properties from which Boeing could choose their desired combination of characteristics. (DX 29; D.I. 418 at 210-14) Boeing chose the "2XXX Goal 1" combination of properties, which had a 30% to 50% slower fatigue crack growth rate and a 20% to 30% higher fracture toughness compared to 2024, with equivalent strength. (DX 28; DX 35; D.I. 418 at 209-10, 219; D.I. 424 at 1780-81) To manufacture 2XXX Goal 1, Ms. Petit predicted that

> some combination of higher purity base metal, controlled Cu and Mg levels, and controlled thermal treatment (especially preheat, reheat and solution heat treatment) would be required.

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[8]During the 1980s, aluminum manufacturers attempted to develop aluminum-lithium alloys, which are lighter than 2024, for use on aircraft fuselage. (D.I. 419 at 361-62; D.I. 420 at 592-94) These attempts failed because of high cost and thermal stability problems. (Id.; D.I. 423 at 1422; D.I. 424 at 1788; DX 35)

(PX 351 at 028333) She recognized that there was a trade-off between strength and damage tolerance properties which required a balancing act so that improving one would not degrade the other, but felt that Alcoa had a "good probability of technical success in producing an alloy with 2XXX Goal 1 properties." (Id.; D.I. 418 at 226-27)

2. Jocelyn Petit's May 1989 Report

17. In a May 1989 report to her colleagues, Ms. Petit stated that

> significant improvements in toughness could be made by one or more of the following approaches: improved base metal purity, controlled Cu and Mg levels, improved thermal practices, modification of dispersoid size and distribution, use of a coherent dispersoid former in place on Mn, refinement of grain size and cold work recovery processes.

(DX 35 at 053172) She further reported that

> [a] new high toughness 2XXX alloy would serve a need for a better fuselage skin material which could potentially be commercialized and implemented within 3-10 years with only a moderate cost impact on the aircraft manufacturer.

(Id. at 053173)

18. Ms. Petit consulted prior work by Dr. James Staley, a senior Alcoa metallurgist, including a 1975 paper on 2124 sheet and March 1989 internal notes on the effect of microstructural features on toughness. (DX 35; D.I. 419 at 276-78) Ms. Petit acknowledged data that indicated that "reduced levels of Fe and

Si would significantly improve the toughness of 2024-T3 sheet."

(DX 35 at 053174) She also noted:

> Sparsely soluble constituent is also present in the 2024-T3 sheet. Much of the composition box for the 2024 alloy contains Cu and Mg in excess of the levels soluble with current preheat, reheat and solution heat treatment processes. This has the advantage of maximizing strength by assuring that Cu and Mg levels up to the solubility limit are in solution and will be available for precipitation strengthening. However, this does lead to retention of coarse S and 2 phase particles in the microstructure and reduction of toughness.
>
> Alloy 2124 for high toughness plate typically gets higher temperature, longer time preheat and reheat practices than does 2024. The preheat for 2024 calls for a 4-hour soak at 870°F while the practice for 2124 calls for 30 hours at 910°F. Use of the more extensive 2124 practices could more thoroughly dissolve S and 2 phases and improve toughness.
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> . . .
>
> An ideal high toughness 2XXX alloy would have lower amounts of both insoluble and sparsely soluble constituent, yet still retain Cu and Mg in levels high enough to achieve strengths equal to current 2024-T3. One scenario by which this could be achieved would be to select an alloy with lower maximum Fe and Si and with restricted Mg and Cu ranges. Restricted Cu and Mg operating ranges should be enabled by Davenport's cast to target procedures. This alloy would then be preheated under optimized conditions similar to those being developed by [Dr. Dhruba Chakrabarti, a senior Alcoa metallurgist] to minimize both furnace time and the amount of coarse second phase for 2124.

(Id.)

19. Ms. Petit concluded:

> [A] 2XXX alloy and processing route could be developed that would have significantly higher toughness than current typical 2024-T3 sheet. The recommended approaches with a high probability of success of significant toughness improvement with minimal development time are:
>
> - use higher purity base metal (lower Fe and Si);
>
> - select Cu and Mg ranges and thermal treatments to maintain maximum levels of Cu and Mg in solution but minimize the levels of 2 and S phase constituent.

(Id. at 053176; D.I. 419 at 289-90)

20. In May 1989, Ms. Petit also obtained samples of 2124 sheet material that Alcoa had produced in 1985, which she submitted for testing. (DX 35; D.I. 419 at 290-92) The test results, received from an outside laboratory on June 2, 1989, reflected that the 2124 sheet had a K_c fracture toughness above 150 ksi/in and a K_{app} fracture toughness above 80 ksi/in. (PX 303; D.I. 419 at 295-97; D.I. 424 at 1714-15)

3. Alcoa's Rifle Shot Trial

21. On the same day that she received the 2124 sheet test results, Ms. Petit recommended a "rifle shot" test at Alcoa's Davenport, Iowa plant ("Davenport") to produce a new sheet material to meet Boeing's request for a higher-toughness fuselage skin. (PX 267) In a memorandum to P.H. McConnaughey, manager at Davenport, Ms. Petit wrote:

> At a projected cost of 1.7 times 2024-T3 Speculair,[9] Boeing's preliminary assessment was that they would use such a material. [Peter Wright, Alcoa's sales representative to Boeing,] has stated that Boeing claims the probability of use of such a material on the 767-X would be high if design allowables were generated by 11/90.
>
> . . .
>
> I have recently reviewed the technical alternatives (letter of 89-05-15) and I believe that we have a high probability of technical success. If Boeing's formal response supports their interest in near term implementation and Alcoa elects to attempt to meet their need, my preliminary recommendations are as follows:
>
> - In the second half of 1989, take a rifle shot approach in a trial at Davenport. I strongly believe that ATC and Davenport could jointly come up with a proposed modified alloy composition and process that would show a significant improvement in toughness compared to standard 2024-T3 Speculair. The proposed practice would be designed to achieve the best toughness improvement at the least cost to plant productivity. At best, our material would meet or exceed the goals and we could make additional lots in 1990 for design allowables. At worst, the material would be only 10-15% tougher and would not meet the Boeing window but the time spent and R & D costs would have been relatively small.

(Id. at 047099)

22. The inventors characterized the rifle shot trial as such because it was a one-time "shot in the dark" attempt to develop an alloy which might be acceptable for Boeing's short-

[9] Alcoa set the price of its new alloy in terms of a "multiplier" over the incumbent 2024-T3 alloy.

term needs with respect to the 777 aircraft.[10] (PX 277 at 051145; DX 55 at 044537)

23. In a July 7, 1989 memorandum to her colleagues, Ms. Petit stated that she and Robert Westerlund, Davenport's chief metallurgist and a named inventor of the '639 patent,

> discussed how to conduct a near term, best effort plant trial, in the event that was elected. There should be one extra high Cu/Mg/2124 ingot left from the preheat trial that could be used. We would preheat it with a standard 2024 practice, but reheat it with a higher temperature practice (i.e., temperatures like a 2124 practice but with a shorter soak time). This was our best compromise based on what we thought would improve toughness with minimal extra thermal practice time.

(DX 82; D.I. 419 at 308-10) Alcoa's 2124 practice used the "417 Process," which contained a high-temperature (910°F) reheat for 30 hours. (D.I. 419 at 309, 520-23; D.I. 423 at 1511-12) In a telex to Ms. Petit on July 18, 1989, Mr. Westerlund stated that in discussing development with Boeing,

> we should treat all information [as] proprietary since there will be nothing patentable. This way, we may be able to keep it from the Japanese (for a while).

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[10] As Mr. McConnaughey noted,

> It should be made clear to Boeing that Alcoa will proceed with a one ingot evaluation; however, the results are what they are. We do not want a program that requires Davenport to "try a little harder" before Boeing can use it. Basically, what you see is what you get!

(PX 269)

(PX 277)

24. Mr. McConnaughey responded that Davenport was willing to support her proposal, using experimental ingots left from a 2124 plate preheat trial and “revised thermal preheat practices.” (PX 269; D.I. 418 at 230) The ingots were referred to as “CU 82” production ingots, and contained a high percentage (4.2%) of copper, outside Alcoa’s production composition range for then-existing 2124 and 2324 plate alloys. (D.I. 419 at 261-63, 305)

25. In a July 25, 1989 letter to Boeing, Mr. Wright wrote:

> In an effort to meet the requirement of design allowables by 1990 November for the 767-X airplane, Alcoa proposes to take a “rifle shot” approach in a plant trial at Davenport during 2H89. The goal will be to match the strength and corrosion resistance of 2024-T3 but improve the toughness by 20-30%.
>
> If we are successful, process optimization and an allowables program could be conducted during 1990. We request that Boeing’s contribution to this effort be to run a wide panel toughness test.
>
> If we are unsuccessful, we do not expect to do any short term tweaking as a part of the goal verification phase of development. Rather, we would defer to a longer, more methodical and comprehensive fuselage alloy development program . . .

(PX 358)

26. In an August 14, 1989 memorandum to her colleagues, Ms. Petit outlined the plans for the rifle shot as follows:

> The approach we plan to use to improve toughness and high)K fatigue crack growth

> resistance is by reducing the amount of both soluble and insoluble constituent present in the final T3 product. This will be done by using higher purity metal, by keeping Cu and Mg content at moderate levels compared to conventional 2024, and by using improved thermal practices.
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> . . .
>
> The trial will consist of three ingots. One ingot will be a 2024 standard composition and two ingots will be CU82 with high side Cu (4.2 Cu, 1.4 Mg). The CU82 alloy is of the 2124 type. All ingots will be processed as alclad. The 2024 ingot will be processed by standard thermal and rolling practices as a control. For the CU82 ingots, one will be preheated 30 hours at 910° and one preheated 4 hours at 870° (standard 2024 practice). All lots will get the standard 2024 reheat.
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> . . .
>
> We estimated that if the trial is initiated now, samples would be available by 1989 November. In late 1989 and early 1990, these samples would be evaluated at ATC for fatigue, toughness, formability and corrosion resistance. Fatigue and toughness tests (48" wide) will be conducted by Boeing on the experimental log. By 1990 January, we should have an indication of whether the improvements are sufficient to be of further interest to Boeing. At that time, a decision will need to be made as to whether to continue the short term work in 1990 to define the composition and process bounds and to generate design allowables. A more detailed time schedule will be generated after production of the trial lots gets underway at Davenport.

(DX 54 at 044512-13) Thus, Ms. Petit focused on the preheat portion of the experiment, considered to be the "critical parameter" for achieving the combination of properties sought by

Boeing, despite the capacity constraints at Davenport. (D.I. 418 at 227-28, 232-33; D.I. 419 at 261-63, 348-49; DX 54 at 044512)

27. Soon thereafter, Mr. Westerlund sent a memorandum to Mr. Sam Shelby at Davenport identifying the parameters for the rifle shot test, characterizing the approach as using "concepts proven on 2124 and 2324 plate and apply[ing] them to sheet." (DX 55 at 044537) He also noted the following:

> If this trial is successful and Boeing decides they would like to include the new alloy on the 767-X, a significant effort remains. First, we would need to determine the sensitivity of properties to composition, preheat and reheat. Second, we would need to run design allowable material (-10 lots).
>
> The schedule will be roughly as follows:
>
> | | |
> |---|---|
> | Trial I | August - October, 1989 |
> | Evaluation of Trial I by Boeing | November - December, 1989 |
> | Trial II - Optimize composition and practices | January - March, 1990 |
> | Trial III - Design allowable material schedule | April - June 1990 |
>
> Based on this schedule, we will be tight for the 767-X, since Boeing would have extensive testing before their November, 1990, material selection deadline, although the 767-X program seems to be slipping.

(Id. at 044537-38)

28. In August 1989, Alcoa metallurgists at Davenport conducted the rifle shot trial using two CU 82 ingots to produce two lots of test alloy, and a third ingot of the standard 2024 alloy as a control lot. (DX 54; D.I. 419 at 312-13) Pursuant to Ms. Petit and Mr. Westerlund's specifications, one test lot was given a high-temperature preheat at 910°F for 30 hours, and the other was given a preheat at 870°F for 4 hours (the 2024 standard preheat). (DX 54; D.I. 419 at 319-22) The control lot was also given the 2024 standard preheat. (Id.) All three lots were to receive Alcoa's standard 2024 reheat, which is a "heat to roll" practice occurring between the first and second hot rollings, in which the material is placed in the furnace just long enough so that it would be sufficiently hot for the second roll. (DX 54; D.I. 419 at 322-23, 351) Although the furnace is set to a specific temperature (910°F) for the 2024 reheat, the material

typically does not reach that temperature.[11] (D.I. 419 at 380-81)

29. In an internal memo dated September 8, 1989, Mr. Wright outlined the minutes of a meeting with Boeing representatives. (PX 274) Mr. Wright reported that

> Boeing will do 60" wide K_{app} test for better validity with this increased toughness material. Samples for Boeing will be available by November. Boeing needs to define the amounts of test material that will be required.
>
> The timetable for this material relative to 767-X is very tight, but Bob Westerlund thinks that the Process Verification Step can be abbreviated because of its similarity to 2024-T3 sheet. Boeing's go/no go decision on allowables is due January 1990 and allowables material should ship by the end of May, 1990.

(Id. at A028348)

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[11] In a 1992 report entitled, "Alloy C188 Development: Characterization and Analysis of Plant Trial Material," two of the inventors explained:

> The reheating step was performed according to a Davenport standard 2024-T3 sheet practice which has since been changed. In the former practice, the furnace temperatures were set at 910°F so the metal got considerably hotter than necessary for the rolling operation. The unintended high temperature reheat had profound effects on the results of the C188 trial and resulted in a different type of practice (other than the trial practice described above) being chosen for the plant verification lots run during the summer of 1990.

(PX 73 at 012599)

30. In December 1989, Ms. Petit and Edward Colvin, an Alcoa metallurgist and a named inventor of the '639 patent,[12] received the initial results of the rifle shot trial from Mr. Westerlund. (PX 414) Although the overall properties were better than anticipated, the results indicated that the first lot (given the high-temperature preheat) had a lower toughness than the second lot (given the lower preheat). (D.I. 419 at 264-65, 349-52, 381) The inventors were surprised that the preheat did not have an effect on the characteristics of the material. (Id. at 265; PX 73 at 012611) As Ms. Petit stated at trial:

> On the one hand we had a really good product, but we had a product that we didn't understand why it worked so good, so we didn't know how to be able to introduce it. So at that point, we started to dig into the samples, do more analysis to better understand how they really were processed and to sort out why they were created with such good properties.

(D.I. 419 at 266)

31. Mr. Westerlund, Mr. Colvin and named inventor Paul Magnusen analyzed the test results to determine why the first lot had a lower toughness. (Id.) Initially, they theorized that the test results were switched. After a microstructural analysis of the two lots, however, they learned that the first lot contained larger particles than the second lot. (Id. at 382-86) Upon

[12] Mr. Colvin became the program leader from 1990 to 1993. (D.I. 419 at 363-64)

review of the furnace records, they discovered that the second lot inadvertently was left in the furnace for over a day during the standard 2024 "heat to roll" step, so the metal actually reached the furnace temperature. (Id. at 386-87) Thus, the second lot received a long, high-temperature reheat step.

32. Mr. Colvin consulted Dr. Chakrabarti, the "resident expert" at Davenport who was performing 2124 reheat and preheat experiments at that time. (Id. at 388-89) Dr. Chakrabarti expressed doubts about using only a reheat step to improve damage tolerance properties. (Id.) Previously, Alcoa attempted to develop improved damage tolerance 2124 plate products using a high-temperature reheating step and no preheat, and was unsuccessful. (Id. at 389-90)

33. The inventors decided to perform microstructural experiments to test the properties of the second lot, which was initially called "C188." (Id. at 390; D.I. 418 at 205; D.I. 424 at 1816)

4. Alcoa's Sales of C188 Samples to Boeing

34. In December 1989, soon after receiving the rifle shot results, Alcoa sold samples of C188 to Boeing, who conducted experiments to test the alloy's suitability as aircraft fuselage skin.[13] (PX 362) Sales orders from Alcoa to Boeing document

[13] These tests included wide-panel fracture toughness tests, barrel tests, and round robin fatigue crack growth rate tests, discussed infra. Alcoa asked Boeing to conduct these tests

several additional "T&E" shipments of C188 samples through mid-1991. (PX 2325; PX 2327; PX 2338; PX 2344; PX 148; PX 398; DX 120) The sales orders contain Boeing's name and shipping address, a description of the material, quantity weight per pound, price[14] and shipping date, and are designated "XBMS" (experimental Boeing material specification). (Id.; D.I. 421 at 972-73) The samples were shipped to Boeing testing facilities in small quantities of four to ten pieces.[15] (D.I. 421 at 969-70; D.I. 424 at 1646) Terms and conditions not expressed in the sales orders were governed by a standard "overriding agreement" negotiated by Alcoa and Boeing in the 1970s. (PX 2325; D.I. 421 at 929-30)

5. Boeing's Wide-Panel Fracture Toughness Tests

35. In January 1990, Boeing conducted fracture toughness tests on 48- and 60-inch panels of C188. (D.I. 424 at 1631; D.I. 419 at 479) The test results reflected that C188 had a high

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because it did not possess the facilities to do so. (D.I. 424 at 1631, 1642; D.I. 419 at 480) The test results were relayed to Alcoa and subject to a proprietary agreement between the companies. (D.I. 421 at 926; D.I. 424 at 1643-44; D.I. 419 at 480-81) Upon completion of the tests, Boeing destroyed the C188 samples. (D.I. 421 at 993; D.I. 424 at 1644)

[14]The special T&E price was originally set at $6.37 per pound and later raised to $12 per pound. (D.I. 421 at 881, 888-89)

[15]During commercial production, Alcoa supplies Boeing's manufacturing facilities with "BMS" material delivered in "ship sets" containing sufficient pieces to manufacture entire airplanes. (D.I. 421 at 969-73; D.I. 424 at 1645-46)

level of fracture toughness and may be suitable for use on an airplane. (D.I. 419 at 480)

6. Peter Wright's January 29, 1990 Letter to Boeing

36. In a letter dated January 29, 1990 entitled, "Design Allowables for Sheet and Plate Products," Mr. Wright wrote the following to Boeing:

> We are on the threshold of commencing with a design allowables program for the referenced material in support of the 777 Program. This is to now advise Alcoa's position regarding funding of that effort as follows:
>
> Alcoa will supply design allowable information per Table 1 attached for ten (10) lots of material as follows:
>
> — Boeing pays $100,000 for delivery of design allowable data, due upon delivery of design allowable data from Alcoa.
>
> — Design allowables will be provided free of charge if a three year production supply contract is signed. Three years begins on date of first production shipment.
>
> — A $50,000 cancellation charge will be in effect after go-ahead from Boeing for design allowables if Boeing subsequently cancels program.
>
> — T&E material to be shipped to Boeing will be sold at $12.00/lb.
>
> — Design allowable data provided by Alcoa is considered to be proprietary data for use by Boeing and Alcoa only.

> — Alcoa will offer a one year exclusive agreement if a three year production contract is signed. Alcoa will not provide design allowable data to any other customer until one year after the date of delivery of that data to Boeing. This aspect is void if the 777 program is not formally launched by four months after delivery of design allowables.
>
> Please advise how you wish to proceed.

(PX 363)

7. Alcoa's ATC Experiment

37. During March and April of 1990, Ms. Petit and Mr. Westerlund performed microstructural testing on C188 by evaluating the effects of different preheating and reheating thermal treatments on the alloy. (D.I. 419 at 390-91; DX 186 at 053019) They sought to develop a thermomechanical process for an upcoming trial in which composition was the variable factor, and to test the extent of cladding diffusion during a high-temperature reheat operation. (DX 186 at 053019-20) Ms. Petit and Mr. Westerlund discovered that they could reduce the size of particles within the alloy by using a high-temperature reheat practice and no preheat practice.[16] (D.I. 419 at 392; DX 186 at

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[16]In a 1992 report, Mr. Colvin and Mr. Magnusen described the inventors' rationale:

> The normal 2024 processing provides adequate heating to prepare the metal for hot rolling operations, but since the temperatures are well below the Cu and Mg solvus the process does not minimize volume fractions of those

053023) They did not perform any damage tolerance testing on C188 at this time. (D.I. 419 at 391)

8. The Parent Applications

38. Based on the results of the rifle shot trial and ATC experiment, Ms. Petit, Mr. Colvin and Mr. Westerlund filed two patent applications in August 1990 (the "parent applications") entitled, "Damage Tolerant Aluminum Alloy Clad Sheet for Aircraft Skin" (U.S. Patent Application No. 572,625) and "Damage Tolerant Aluminum Alloy Sheet for Aircraft Skin" (U.S. Patent Application No. 572,626). (DX 640; DX 641)

39. The parent applications describe the invention as relating to

> aluminum alloys suitable for use in aircraft applications and more particularly,

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> phases. Therefore 2X24 products with improved properties have been produced using high temperature, long time preheats. Generally the ingots are heated to temperatures in excess of 910°F for approximately 30 hr to minimize 2 and S volume fractions. In the case of 2124 plate, there is also a high temperature reheat between hot rolling operations. The extended times at temperature are needed to dissolve the constituent particles because they are very large and tend to cluster as the ingot solidifies. Using the more effective thermal practices for C188 allows the Cu and Mg to be lowered from the nominal 2024 values because dissolution of the soluble constituent particles leaves more of those elements in solid solution and, hence, available for strengthening.

(PX 73 at 012597)

> [relating] to an improved aluminum alloy and processing therefor having improved resistance to fatigue crack growth and fracture toughness and suited to use as aircraft skin.

(DX 640 at 245146; DX 641 at 245299) As an example of the invention, the parent applications describe the composition, processing and properties of the clad alloy manufactured during the rifle shot trial.[17] (DX 640 at 245149-59; DX 641 at 245302-11)

40. Alcoa submitted several prior art references with the parent applications, including United States Patent Nos. 4,294,625 (Boeing's "Hyatt patent"), 3,726,725, 3,826,688, 4,294,625 and 4,336,075. (DX 640 at 245198-201; DX 641 at 245350-53)

41. In an Office Action dated August 22, 1991, the patent examiner rejected all of the process claims as anticipated by United States Patent No. 4,816,087 (the "Cho patent"), which teaches a high-temperature reheating step in making aluminum-lithium alloys. (DX 640 at 245207-14; DX 641 at 245359-65) The patent examiner rejected all of the claims (product and process) as obvious from the Cho patent in light of the Hyatt patent, which claims 2324 plate. (Id.)

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[17]This became Example 1, Part 1 and Example 2, Part 1 of the '639 patent. (DX 188, col. 14, lns. 39-50, col. 16, lns. 16-32; D.I. 423 at 1484-85)

42. In a February 21, 1992 response, the applicants amended the claims and distinguished the Cho patent because it described an alloy composition and reheating temperature outside the amended ranges. (DX 640 at 245219-66; DX 641 at 245370-401) Regarding the obviousness rejection based on the Cho patent in light of the Hyatt patent, the applicants argued:

> [T]he rejection asserted in the Office Action has not adequately explained why it would be obvious for someone to combine Cho's Al-Li alloy duplex structure processing with Hyatt's apparently conventional structure in an Al-Cu-Mg alloy. The alloys are different! The mere fact that both references seek to improve their respective different alloys by different thermal mechanical treatment alone does not suggest any combination. Any such combination of necessity requires picking this feature from one reference and combining it with that feature from the second reference with no suggestion within either reference to do so, a practice that is not appropriate in framing an obviousness rejection.
>
> . . .
>
> What reason is shown in Cho, who says his product has toughness, to look to Hyatt's different process for a different alloy? Would Hyatt's process achieve Cho's desired duplex structure? Similarly why would Hyatt look to Cho who is talking about a different alloy? Thus, what would one find if one took Hyatt's disclosure and tried to use Cho's processing (ignoring for a moment that the person involved wasn't concerned with duplex structure)? Would that person heat to 980° as Cho recommends? It is again pointed out that the Applicants' present method claims are limited to 945°F in the reheat step and that differs substantially from Cho's teachings. Accordingly it is respectfully

> submitted that there is no proper basis in either Hyatt or Cho to combine the two references. It is further submitted that any such combination would point away from the Applicants' present claims unless the combination is somehow arrived at using the Applicants' specification as a road map, a procedure which has been condemned by the Court of Appeals for the Federal Circuit.

(DX 640 at 245257-58; DX 641 at 245398-99) (emphasis omitted)

43. The patent examiner ultimately allowed the parent applications, but Alcoa later abandoned them after the inventors performed additional work on C188. (DX 640 at 245281-82, 245285; DX 641 at 245420-21, 245424; D.I. 423 at 1483-84)

9. Alcoa's Plant Verification Trial

44. During the summer of 1990, Ms. Petit and Mr. Westerlund conducted the plant verification trial at Davenport, which addressed

> composition variation that would reasonably be expected during normal production, the effect of low temperature hold after the high temperature reheat soak, and solution heat treatment using the vertical heat treater rather than the 86 inch continuous temper line.

(DX 186 at 053025) They also performed tensile strength, fracture toughness and fatigue crack growth rate testing. (Id. at 053026-29)

45. Ms. Petit and Mr. Westerlund's evaluation of the plant verification trial continued into 1991. (Id. at 053019; D.I. 419 at 392-93) In a January 1993 report, Mr. Colvin detailed the

following conclusions drawn from the plant verification trial and the ATC experiment:

1. ATC and plant experiments show the damage-tolerant properties of C188 can [be] achieved using a relatively short high-temperature soak at the slab reheat stage of fabrication. No long time, high temperature presoak is needed; in fact, practices of this type may result in the formation of large particles that detrimentally impact damage tolerance.

2. There is room for variation in Cu and Mg content to achieve required properties. The proposed composition box for C188 appears to be appropriate but the ultimate tensile strength of material at the low Cu and low Mg corner falls right at the specified minimum. An ingot with near maximum Cu and Mg gave very good damage-tolerant properties.

3. Slight increases in Mn content increase strength. There was a slight decrease in toughness associated with the strength increase but fatigue crack growth resistance was not adversely affected.

4. The experiments showed that, after the reheat, time at temperatures significantly below the solvus must be minimized because soluble particles grow rapidly due to the large amount of excess solute and rapid diffusion at these temperatures. These particles reduce fracture toughness and resistance to fatigue crack propagation.

5. Volume fraction of 2 and S particles controls grain size in C188 when other factors are held constant. This probably results from a PSN mechanism.

6. Cu diffusion to the surface of alclad sheet during the reheat operation does not appear to be a problem. The lot that received a 24 hour reheat exhibited no more diffusion than the other lots.

(DX 186 at 053031)

10. The "Partners Through the Millenium" Proposal

46. In a memo dated June 26, 1990 to his colleagues, Mr. Wright noted that there is a "connection between new alloy pricing and the placement of several packages" of existing non-C188 alloys. (PX 376 at 003029) He described "an analysis we've done to explore the value to Boeing of reducing our new alloy premiums" and recommended that Alcoa reduce the price it set for C188. (Id.) In connection with a price reduction, Mr. Wright hoped to secure the extension of other contracts Alcoa had with Boeing. (Id. at 003032)

47. In September 1990, pursuant to Mr. Wright's recommendations, Alcoa made a presentation to Boeing entitled, "Partners Through the Millenium" (the "Millenium proposal"). (PX 378) The Millenium proposal had four basic parts: (1) a request for a commitment by Boeing to maintain Alcoa's share of business for a larger number of airplanes, together with a commitment by Alcoa to expand its production facilities; (2) an extension of the Mill Finish Sheet Contract, including upward price revisions for Alcoa's products; (3) an extension of the Wing Plate Contract, also with upward price adjustments; and (4) a reduction in new alloy pricing, including a 1.25 multiplier for C188. (Id. at 003053-72)

48. Specifically, the Millenium proposal provided for the lower C188 multiplier during the four-year rollout plan for Boeing's 767-X airplane (1994 to 1997). (Id. at 003072) Thus, it provided for the new lower price during commercial production of C188. (D.I. 421 at 1001) The Millenium proposal estimated that the quantity of C188 that Alcoa would sell to Boeing during that four-year period would be 6.86 million pounds, at a total cost of $51.45 million. (Id.) It stated that this would provide a cost savings to Boeing of $10.29 million compared to the previous multiplier. (Id.)

49. The Millenium proposal also stated that its four parts are "interdependent" and that the deal "depends on acceptance of all four parts." (Id. at 003043) The final page of the proposal asked for either Boeing's response by November 1, 1990 or that Boeing "[a]ssign P.O. Number now in this space_____." (Id. at 003083)

11. Boeing's Barrel Tests

50. During February 1991, Boeing conducted "barrel tests" on C188 samples purchased from Alcoa to measure fatigue crack growth rate and fracture toughness. (D.I. 419 at 480-81; D.I. 418 at 181-83; D.I. 422 at 1180; D.I. 424 at 1633) The tests involved shaping 60-inch-wide panels of the alloy into tube-like airplane fuselage and subjecting them to tests as if they were flying. (D.I. 419 at 480-81; PX 448 at 009184-85)

51. In March 1991, Boeing reported to Alcoa the barrel test results, which confirmed that C188 had very high fracture toughness and resistance to fatigue growth as compared to the incumbent 2024. (D.I. 419 at 481; DX 117) Mr. Dan Goodyear, an Alcoa application engineer that communicated with Boeing, summarized the results for the inventors:

> C188 clearly illustrated the superior toughness over 2024. Boeing earlier has said in using C188 that a 3-4% weight savings could be realized by reducing the frame gage.
>
> In summary, C188 will provide not only a premium over 2024 but also additional volume. The Japanese subcontractors who would buy from domestic aluminum producers now have to purchase Alcoa produced C188.
>
> Rudy Shad, 777 structures manager, stated that the C188 alloy was one of the success stories for the 777 aircraft. This unique success story is due to many people who worked and are working as a team to accomplish a common goal in less than a 2-yr. span. Some of these individuals are Wes Wells, Bob Westerlund, Jocelyn Petit, Ed Colvin and Pete Wright.
>
> The C188 alloy program is not complete however. Davenport in its effort to meet the 777 window of opportunity has combined several steps which include commercial development and validation of C188. The material for alloy allowable generation is now being produced. The program will continue to require a diligent, watchful eye to assure continuing success.

(DX 117 at 009020)

12. Alcoa's Design Allowables Testing

52. The inventors began the design allowables phase of development in August 1991, and testing continued in 1992. (DX 186 at 053031) Design allowables testing is one of the final components of the development stage; it confirms the characteristics of the product and processes for manufacturers to use when designing the airplane. (D.I. 419 at 394; D.I. 424 at 1627-28; D.I. 421 at 974-75) During this phase, the inventors first developed a guaranteeable fatigue crack growth rate. (D.I. 419 at 492-94, 457-60, 534) In October 1991, Alcoa forwarded initial test results to Boeing. (D.I. 421 at 975-83; D.I. 424 at 1629; DX 705)

53. The design allowables phase was completed approximately nine months behind schedule. (D.I. 424 at 1624) Alcoa spent about $3 million on the entire C188 development effort, which Ms. Petit stated took three years to complete. (D.I. 419 at 342-43, 404)

13. Boeing's Round Robin Tests

54. In November 1991, Boeing conducted "round robin" tests of fatigue crack growth rate values to be certain that C188 was superior to 2024 when tempered for use as a dome-shaped aft pressure bulkhead. (DX 150; D.I. 419 at 490-92) According to an Alcoa Quarterly Status Report, this "new fatigue information [was] incorporated into the revised patent application . . .

[which] . . . caused filing to be delayed until early 1992." (DX 159) The round robin tests were completed by the end of 1991. (D.I. 419 at 492-93)

14. The Continuation-in-Part Application

55. On March 6, 1992, the inventors filed a continuation-in-part ("CIP") application with the PTO, which incorporated the plant verification trial, design allowables results and Boeing's development efforts. (D.I. 419 at 404, 492-94; D.I. 159 at 024329) As compared to the parent applications, the CIP application contained nine additional figures, K_{app} values (the parent applications expressed only K_c values), guaranteeable fatigue crack growth rate values, different testing procedures, different strength levels, and increased manganese in composition. (DX 188; D.I. 419 at 400-04, 494-97) The application also added Mr. Magnusen as an inventor, since he developed the guaranteeable fatigue crack growth rate properties in early 1992. (D.I. 419 at 475-77, 493-94; DX 159 at 024329)

56. Throughout the prosecution of the parent applications and the CIP application, the applicants did not disclose Alcoa's 417 Process used with 2124 plate products, the composition of the 2124 alloy, Dr. Staley's publication on 2124 or the results on toughness tests performed on 2124 sheet shortly before the rifle shot trial. (D.I. 419 at 509, 528; D.I. 423 at 1482) The applicants also did not disclose a reheating step that they

previously used to make 2024 fuselage during which "the furnace temperatures were set at 910°F so the metal got considerably hotter than necessary for the rolling operation."[18] (PX 73 at 12599; D.I. 423 at 1316-17)

57. The CIP application was prosecuted by Carl Lippert, Alcoa's attorney, who testified that he spoke to the inventors about the importance of disclosing all material art to the Patent Office, discussed and reviewed each submission with them, and tried to make sure that the application was correct. (D.I. 425 at 2073-98) Ms. Petit also testified that she discussed the application with the other inventors and "was not aware of anything that had been left out." (D.I. 419 at 534)

58. In October 1992, the patent examiner issued a Notice of Allowability for claims 1 through 232 of the '639 patent, and stated that

> [t]he prior art search has not produced any references which teach, disclose, or suggest applicants' claims to a thermomechanical process for making Al-Cu-Mg alloy stock

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[18] The parent applications compared the invention with a lot of standard 2024, which was incorrectly described as "processed the same [as the invention material] except it was not subject to reheating at 910°F." (DX 640 at 245157-58; DX 641 at 245309-10; D.I. 419 at 512-13) The inventors later discovered that the control lot during the rifle shot trial also inadvertently received the long, high-temperature reheat. (D.I. 419 at 510-13) As a result, the CIP application amended the description to read: "It is to be noted that the 2024 comparison product does not represent typical commercial 2024 because the comparison product received processing according to the invention." (DX 642 at 244902)

> material. These high-copper, no-lithium Al alloys utilize a re-heat step before hot working and solution heat treating stages.

(DX 642 at 245085)

15. Commercial Production

59. The commercial phase of the C188 project began in March/April 1992 when Alcoa began shipping material to Boeing's Japanese subcontractors. (D.I. 424 at 1625, 1646; D.I. 421 at 979-80; DX 155; DX 161) Lot release testing, where Boeing directs that certain tests be put in the specification of the commercial material, began in May 1992. (D.I. 424 at 1652)

60. In January 1996, the Aluminum Association granted Alcoa's request for the international alloy designation "2524" for C188. (Id. at 1817)

61. Boeing uses 2524 on its 777 aircraft.[19] (D.I. 418 at 164) Alcoa also sells 2524 for use on Bombardier's Global Express business jet, Airbus' new A340 derivative, and the Embraer 170, a regional jet that carries 70 people. (D.I. 424 at 1653) By the end of 2000, Alcoa sold 17 million pounds of 2524 production material to Boeing, 1.2 million pounds to Bombardier, 400,000 pounds to Airbus, and 185,000 pounds to Embraer. (Id. at 1653-55)

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[19]Boeing continues to use 2024 on the 747 aircraft and the redesigned 737 aircraft because of geometrical requirements that make 2524 unsuitable. (D.I. 421 at 946-47; D.I. 424 at 1654-55)

D. The '639 Patent

62. On May 25, 1993, the '639 patent, entitled, "Damage Tolerant Aluminum Alloy Products Useful for Aircraft Applications Such as Skin," issued to Alcoa as assignee. (DX 188) Ms. Petit, Mr. Westerlund, Mr. Colvin and Mr. Magnusen are listed as the named inventors. (Id. at 1)

63. The '639 patent discloses an aluminum alloy composition with reduced impurities to minimize insoluble particles and controlled levels of alloying elements combined with a manufacturing process that includes an intermediate high-temperature reheating step to minimize undissolved soluble particles. (Id., cols. 3-4; col. 5, lns. 44-49) This alloy has an "improved resistance to fatigue crack growth and fracture toughness and [is] suited to use as aircraft skin." (Id., col. 1, lns. 16-18) The damage tolerance and strength properties of the improved alloy are "guaranteeable." Those guaranteeable properties "translate[] to improved safety for passengers and crew and weight savings in the structure which allows for improved fuel economy, longer flight range, greater payload capacity or a combination of these." (Id., lns. 28-32)

64. The patent contains 232 claims, consisting of 142 product claims, 89 process claims and 1 product-by-process claim. (Id., cols. 22-42) The product claims (70-103, 125-232) claim various aluminum products within the same compositional ranges

and having different combinations of strength, fracture toughness and/or resistance to fatigue crack growth, or a 5% improvement over "2024 alloy" in those two damage tolerance properties. The process claims (1-69, 104-123) claim steps to manufacture aluminum alloy products with varying but similar 2024-type compositions, including an intermediate reheating step between steps of hot rolling. The product-by-process claim (124) claims products produced by methods described in certain of the process claims. (Id.)

65. The asserted claims recite either an "aluminum alloy sheet product," an "aluminum alloy sheet or plate product," or an "aluminum alloy product." Each product must be formable and corrosion resistant, and its damage tolerance properties must be guaranteeable. Some claims are limited to clad products, whereas others encompass both clad and bare products. Thirty-eight of the asserted claims recite a particular aircraft application, such as "aircraft skin." (DX 188; D.I. 385) The asserted claims may be divided into five categories based on their properties:

> (1) claims reciting a "clad product" having certain fracture toughness "and" fatigue crack growth rate properties (80, 141, 216, 225);
>
> (2) claims reciting a "product" having certain fracture toughness "and" fatigue crack growth rate properties (75, 138, 149, 159);
>
> (3) claims reciting a "clad product" having certain fracture toughness "or" fatigue crack

growth rate properties (78, 86, 91, 95, 99, 103, 139, 142, 150, 153, 160-61, 164, 218, 221, 223, 226, 229);

(4) claims reciting a "product" having certain fracture toughness "or" fatigue crack growth rate properties (72-73, 87, 89, 93, 97, 101, 136, 143-47, 151-52, 154-57, 162-63, 165-66, 214, 219-20, 222, 227-28, 230); and

(5) claims reciting a "product" having a minimum fracture toughness K_{app} of 80 ksi√in or more (claims 192-95).

66. The tightest compositional limits recited by the asserted claims are: 4.0-4.5% Cu, 1.2-1.5% Mg, 0.4-0.7% Mn, maximum 0.15% Fe and maximum 0.12% Si. The minimum K_c value is 140 ksi/in, the minimum K_{app} value is 80 ksi/in, and the minimum transverse yield strength is 40 ksi. The asserted claims also provide for a fatigue crack growth rate not greater than that shown at one or more levels in Figures 8 and 9 of the specification. (DX 188)

E. Pechiney's 2024A Alloy

67. In 1996, Airbus, a consortium of European aircraft manufacturers, asked Pechiney to develop an aluminum alloy to compete with Alcoa's 2524 alloy for potential use as fuselage skin on the Airbus A340-500/600 aircraft. (D.I. 424 at 1817) The alloy that Pechiney developed in response to this request received a "2024A" designation from the Aluminum Association. (Id.)

68. In July 1997, Pechiney submitted to Airbus a Qualification Report concerning the two products it had produced and characterized, a thin-gauge clad 2024A product and a thicker, bare 2024A product. (PX 2387; D.I. 422 at 1094) The Qualification Report identifies the average chemical composition of 2024A as 4.061% Cu, 1.303% Mg, 0.412% Mn, 0.066% Fe and .038% Si. (PX 2387 at 176909) The internal operating limits of Pechiney's "2024-15" composition, which is used to make 2024A, identify the target composition for 2024-15 as 4.05% Cu, 1.32% Mg, and 0.4% Mn with a maximum of .09% Fe and .08% Si. (DX 524 at 322075; D.I. 420 at 688-89)

69. The Qualification Report also indicates that 2024A is formable and resistant to corrosion. (PX 2387 at 176911, 176932; D.I. 420 at 634; D.I. 422 at 1137-38)

70. In early 1998, Airbus qualified the two products for use on its A340-500/600 aircraft. (PX 1773; D.I. 424 at 1817-18; D.I. 420 at 633) In June 1998, Airbus issued an individual product specification for 2024A products on the basis of the Qualification Report. (PX 2212; D.I. 422 at 1105-06)

71. On November 10, 1997, Boeing requested that several aluminum alloy companies, including Pechiney, propose prices for various aluminum alloy products. (D.I. 424 at 1818) On December 23, 1997, Pechiney sent a proposal to Boeing in which it indicated that between 1.5 and 2.5 million pounds of 2024A alloy

would be available for purchase each year, with delivery to start in 1999. Pechiney also quoted shipping charges for delivery to the United States.[20] (Id. at 1818-19; DX 405)

72. Robert Macé, Pechiney's Director of Research, testified that 2024A "matches" the composition and properties covered by the asserted claims of the '639 patent. (D.I. 420 at 620; D.I. 423 at 1300) Guy-Michel Raynaud, a Pechiney senior metallurgist, and Professor James C. Williams, Alcoa's metallurgical engineering expert, also confirmed that the composition of 2024A falls within the asserted claims. (D.I. 422 at 1136-39, 1156-57; D.I. 420 at 694-95)

73. Professor Richard W. Hertzberg, Alcoa's materials testing expert, conducted tests on samples of 2024A to confirm that the alloy fell within the properties of the asserted claims. Professor Hertzberg performed fifteen tests for yield strength, twelve tests for fatigue crack growth rate and nine tests for fracture toughness. (D.I. 420 at 741, 748, 758) Based on the results of his testing and the Qualification Report, Professor Hertzberg concluded that the yield strength, fatigue crack growth rate and fracture toughness of 2024A were guaranteeable values that fell within the properties of most of the asserted claims. (Id. at 741-66)

[20]The parties do not dispute that this constituted an offer to sell 2024A in the United States. (D.I. 425 at 2053)

74. On September 29, 1999, Pechiney made a slide presentation to Airbus, during which Pechiney admitted that 2024A is "in the scope of" the '639 patent, but that the validity of the patent is "questionable." (DX 508 at 317407; D.I. 420 at 627-28)

F. Prior Art[21]

1. The Staley Reference

75. Dr. Staley authored a paper entitled, "Microstructure and Toughness of High-Strength Aluminum Alloys," which was published by the American Society for Testing and Materials in 1976. (PX 585A) The paper sought "to illustrate the relationship between certain microstructural features and the toughness of wrought, high-strength aluminum alloys and to present examples of alloys developed to have high fracture toughness." (Id. at 043973) Dr. Staley focused on 2XXX and 7XXX alloys. (PX 585A)

76. The Staley reference teaches that an alloy's base purity can be increased by removing iron and silicon from its composition, and strength can be increased by refining the size of soluble constituent particles by thermal mechanical treatments. (Id.; D.I. 423 at 1350) The paper states:

[21]Pursuant to the court's rulings on the parties' motions in limine, Alcoa's 1985 sheet trial (2124 alloy) and Pechiney's 1982 sheet production (2324 alloy) were not public and, therefore, are not considered prior art to the '639 patent. (D.I. 384)

> Thermal mechanical treatments prior to solution heat treatment can also increase toughness by modifying the size, distribution, and volume fraction of the partially soluble constituent particles. For example, decreasing the size of the Al_2CuMg particles in high-purity 2124 sheet from a range of about 10 to 20 µm to a range of about 5 to 10 µm by thermal mechanical treatments increased tear resistance (Fig. 3) and decreasing the volume fraction of the Al_2CuMg particles in 7050 plate increased notch toughness (Fig. 4).

(PX 585A at 043975-76) "Fig. 3" contains a graph depicting the composition of the 2124 sheet material (4.1% Cu, 1.5% Mg, 0.6% Mn, .04% Si, .04% Fe), and "estimated" K_c fracture toughness data points. (Id. at 043977; D.I. 423 at 1350-51)

77. Dr. Staley made the following conclusions:

> In summary, the effects of soluble and insoluble constituents, dispersoids, and hardening precipitates on toughness of high-strength aluminum alloys are fairly well established. The following guidelines are offered to increase toughness by modifying these particles:
>
> 1. Minimize the volume fraction of insoluble constituents by increasing base purity.
>
> 2. Refine the size of soluble constituent particles by thermal-mechanical treatments.
>
> 3. Decrease the number of dispersoids by adjustments in chemistry or by thermal-mechanical treatments.
>
> 4. Quench as rapidly as possible.
>
> 5. Do not overage 2XXX alloy products.

6. Minimize cold work of 7XXX alloys before aging.

7. Where low residual stress is required, quench as rapidly as possible and mechanically stress relieve rather than quench slowly.

8. Age a lower-solute alloy to peak strength rather than overage a higher-solute alloy.

9. Reduce magnesium in 7XXX alloys to lowest level consistent with desired strength.

10. Where rapid quenching cannot be attained, as in plate, adjust practices to promote the lowest degree of recrystallization.

(PX 585A at 043993-95)

78. The Staley reference does not address K_{app} values, fatigue crack growth rate, clad products or guaranteeability, nor does it show K_c testing.[22] (Id. at 043977; D.I. 423 at 1441)

2. The Truckner Reference

79. In 1976, Alcoa published a report on behalf of the Air Force Materials Laboratory entitled, "Effects of Microstructure on Fatigue Crack Growth High-Strength Aluminum Alloys." (PX 596) The report describes a study conducted by Dr. Staley and fellow Alcoa metallurgists Drs. W.G. Truckner, Robert J. Bucci and A.B. Thakker "to provide guidance for development of optimum

[22]Upon conversion to K_c values, Dr. Staley's "estimated" damage tolerance figures do not fall within the asserted claims. (D.I. 494 at ¶ 20.3)

metallurgical structures to retard fatigue crack growth in high-strength aluminum alloys, yet maintaining essential mechanical and physical properties." (Id. at 1) The study examined 2XXX and 7XXX alloys. (Id.)

80. The authors concluded the following:

> 1. Strengthening precipitate had the largest effect on fatigue crack propagation rate at)K levels above about 4 ksi/in.
>
> 2. Amounts of the major alloying elements had the largest effect on fatigue crack propagation rate at)K levels below about 3 ksi/in.
>
> 3. Increasing dislocation density as modified by stretching 2XXX alloys after quenching had a lesser but statistically significant effect on increasing fatigue crack propagation rate.
>
> 4. Insoluble constituent particles had little effect and dispersoid particles had no effect on fatigue crack propagation rate at)K levels much below about 15 ksi/in for both 2XXX and 7XXX alloys.
>
> 5. Grain size from 5 to 65,000 grains per mm^3 had no effect on crack growth rate in peak and overaged 7XXX alloys.

(Id. at 9)

81. The Truckner reference contains no K_{app} data or guaranteeable K_c data. (PX 596; D.I. 424 at 1696-98, 1742)

3. The Bucci Reference

82. In 1979, Dr. Bucci authored an article entitled, "Selecting Aluminum Alloys to Resist Failure by Fracture Mechanisms" to "provide useful information and guidelines to

engineers seeking to minimize fracture-type failure in aluminum structures through better application of materials knowledge and optimum alloy choice." (PX 654 at 237955)

83. The article discusses how to achieve "controlled-toughness, high strength alloys" such as 2124-T3 and T8-type sheet and plate. (Id. at 237961; D.I. 423 at 1369-70) Specifically, Dr. Bucci states:

> Alloy 2124 was the first 2XXX alloy developed for high fracture toughness. The principal contribution to high toughness was increased purity (low iron and silicon) which minimizes formation of relatively large insoluble constituents (> 1 :m) that crack first and initiate void growth. . . . Biggest gains in fracture toughness of 2XXX alloys by process control have been to the precipitation hardened T8 tempers which are widely used in applications requiring good resistance to exfoliation corrosion and SCC [stress corrosion cracking]. . . .
>
> Controls on production processes for high toughness alloys 2124 and 7475 do not decrease fatigue and SCC resistance below that of their respective 2024 and 7075 counterparts at comparable tempers. In fact, the improved toughness has been shown to increase fatigue crack growth resistance at high crack growth rates.

(PX 654 at 237962-64)

> Controls on alloy processing and heat treatment are key to assurance of high resistance to SCC without appreciable loss in other mechanical properties. Artificial aging 2XXX alloys to precipitation hardened T8 tempers provides relatively high resistance to exfoliation, SCC, and superior elevated temperature characteristics with modest strength increase over their naturally

> aged counterparts. In recent years, significant progress has been made in improving fracture toughness of 2XXX alloys in T8 tempers. Alloy 2124-T851 (also known as Alcoa 417 Process 2024-T851) has had over 13 yr of experience in military aircraft with no record of SCC problems.

(Id. at 237970)

> With 2XXX alloys more corrosion resistant, precipitation hardened T8-type tempers provide a better combination of strength and fatigue resistance at high endurances than naturally aged T3 and T4 tempers. However, artificial aging of 2XXX alloys is accompanied by loss in toughness with resultant decrease in fatigue crack growth resistance at intermediate and high stress intensities.
>
> Interaction of a clad protective system with fatigue strength of alloys 2024-T3 and 7075-T6 in air and sea water environments are shown in Fig. 27. In sea water, benefits of the cladding are readily apparent. In air the cladding appreciably lowers fatigue resistance.

(Id. at 237980-81)

> Other Alcoa works were able to establish statistically significant effects of alloy microstructure and composition on fatigue crack growth resistance of high strength aluminum alloys. . . . Good fatigue crack growth resistance of 2XXX alloys show high correlation with increasing toughness and/or decreasing strength.

(Id. at 237981-82)

84. The Bucci reference does not contain any K_{app} data, nor does it contain any guaranteeable K_c data. (PX 654; D.I. 424 at 1742)

4. The Neshpor Reference

85. In 1983, Soviet scientists G. S. Neshpor, V. V. Teleshov and A. A. Armyagov conducted a study entitled, "Effect of Chemical Composition and Heat Treatment on the Characteristics of the Structural Strength of Plates of Alloy D16," the results of which were published in English the following year. (PX 2289; D.I. 423 at 1376-77) Alloy D16 is the Russian equivalent of the 2024 alloy. (Id. at 1376)

86. The fracture toughness values in the Neshpor reference are lower than those found in the '639 patent and were measured using L-T (longitudinal) samples. (D.I. 424 at 1689-92) Furthermore, there is no discussion of formability, corrosion resistance or guaranteeability. (Id.)

5. The Hyatt Patent

87. The Hyatt patent issued to inventors Michael V. Hyatt and William E. Quist, and assignee Boeing on October 13, 1981. (PX 2265A) The Hyatt patent "relates to aluminum alloys, and more particularly to a 2000 series alloy of the aluminum-copper-magnesium type characterized by high strength, very high fatigue resistance and very high fracture toughness." (Id., col. 1, lns. 10-14) The invention aims to "provide an aluminum alloy for use in structural components of aircraft that has a higher strength to weight ratio than the currently available alloy 2024-T351" and "provide this aluminum alloy with improved fatigue and fracture

toughness properties while maintaining stress corrosion resistance and exfoliation corrosion resistance at a level approximately equivalent to that of alloy 2024-T351." (Id., lns. 56-64) The commercial embodiment of the claimed invention is Boeing's 2324 plate product. (D.I. 419 at 519, 539)

88. The specification of the Hyatt patent summarizes the invention as follows:

> The desired combination of properties of the 2000 series aluminum alloy of the present invention are achieved by precisely controlling the chemical composition ranges of the alloying elements and impurity elements, by maintaining a substantially unrecrystallized microstructure in the alloy for extruded products, and for plate products, by preaging and cold rolling to increase the strength of the alloy to high levels. The alloy of the present invention consists essentially of 3.8% to 4.4% copper, 1.2% to 1.8% magnesium, 0.3% to 0.9% manganese, the balance of the alloy being aluminum and trace elements. Of the trace and impurity elements present, the maximum allowable amount of zinc is 0.25%, of titanium is 0.15%, and of silicon is 0.12%. For any other trace elements present in the alloy, the maximum allowable amount of any one such elements is 0.05% and the total allowable amount of the other trace elements is 0.15%. For plate products, the maximum iron and silicon levels are preferably restricted to 0.12% and 0.10%, respectively. Once the alloy is cast, it is hot worked to provide a wrought product, such as extrusions or plate. The product is then solution treated, quenched, stretched and thereafter naturally aged at room temperature. In addition, the plate products are preaged and cold rolled 11±2% prior to stretching. The high-strength of the invention alloy is achieved by the preaging and cold rolling

> procedure for plate products and by carefully controlling the extrusion parameters for extrusion products to avoid substantial recrystallization in the product. The fracture toughness and fatigue resistance of the alloy of the present invention are maintained at a high level by close control of chemical composition and also by the aforementioned processing controls.

(PX 2265A, col. 2, lns. 13-47)

89. The Hyatt patent discloses a high-temperature homogenization treatment at 920°F, but not a high-temperature reheat practice.[23] (Id., col. 3, lns. 56-61; D.I. 419 at 525) The Hyatt patent does not address clad products, nor does it claim a formable product for use as aircraft fuselage skin. (D.I. 424 at 1706-07, 1739)

6. Processes in the Prior Art

90. A 1971 article by Harold Marcus and Dr. Thomas E. Sullivan published in Army Research and Development News Magazine describes homogenization as a means for dissolving particles in high-strength aluminum alloys. (PX 821) Although the article focuses on 7XXX series alloys (in experiments on 7075, a homogenization temperature of 900°F produced a completely homogenous material), it also states that the process is applicable to 2XXX and 6XXX series alloys. (Id.)

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[23]Nevertheless, Professor Edgar A. Starke, Pechiney's metallurgy expert, testified that the Hyatt patent has "got the whole recipe for the Alcoa invention." (D.I. 423 at 1415)

91. An Air Force report by Mr. Hyatt in September 1973 discusses ways to improve fracture toughness and fatigue crack growth resistance in sheet and plate through good homogenization processing. (PX 2240; D.I. 423 at 1408) The report describes the process for homogenizing the 7050 alloy (also applicable to the 2XXX series) as follows:

> cast D.C. ingot, preheat 20 hr at 860°-870°F, hot roll at 750°F, preheat 10 hr at 860°-870°F, hot roll at 750°F, solution heat treat 9 hr at 890°-900°F, quench, and age. This extended homogenization treatment, or a 24 hr solution treatment at 890°F following a 20 hr homogenize at 860°F and hot rolling, markedly reduces the volume fraction of $CuAl_2$ in the final 7050 material. . . .

(PX 2240 at 245601)

92. A January 1983 National Bureau of Standards report entitled, "Processing/Microstructure/Property Relationships in 2024 Aluminum Alloy Plates" also describes a high-temperature homogenization step to reduce impurities after hard working the ingot. (PX 2279; D.I. 423 at 1406)

93. Throughout the 1970s and 1980s, Alcoa used its 417 Process to improve damage tolerance of 2124 bare plate products. The 417 Process contains high-temperature preheat and reheat steps of 30 hours at 910°F, and a subsequent reset step whereby the furnace is set to a specific temperature and then lowered to cool the metal to the lower temperature. The 417 Process ends with a long duration solution heat treatment. (D.I. 419 at 520-

23; D.I. 423 at 1511-12) The reset and solution heat treatment are contrary to the teachings of the '639 patent. (DX 188, col. 7, lns. 5-10, 39-42; D.I. 423 at 1560-61; D.I. 419 at 373-77, 521)

7. Cladding in the Prior Art

94. Cladding is a well-known practice that has been used since the 1920s, commonly with fuselage skin products. (D.I. 423 at 1393; D.I. 424 at 1728-30)

III. CONCLUSIONS OF LAW

A. Literal Infringement[24]

1. Alcoa contends that Pechiney's 2024A alloy literally infringes the asserted claims of the '639 patent.

2. A determination of infringement requires a two-step analysis. First, the court must construe the asserted claims so as to ascertain their meaning and scope. Second, the claims as construed are compared to the accused product. See KCJ Corp. v. Kinetic Concepts, Inc., 223 F.3d 1351, 1355 (Fed. Cir. 2000). Claim construction is a question of law while infringement is a question of fact. See id. To prevail on an allegation of infringement, a party must establish by a preponderance of the evidence that the accused product infringes one or more claims of the patent. See Advanced Cardiovascular Sys., Inc. v. Scimed

[24]Because Alcoa did not submit willful infringement at trial, the court finds that Alcoa has waived the issue.

Life Sys., Inc., 261 F.3d 1329, 1336 (Fed. Cir. 2001). To establish literal infringement, "every limitation set forth in a claim must be found in an accused product, exactly." Southwall Tech., Inc. v. Cardinal IG Co., 54 F.3d 1570, 1575 (Fed. Cir. 1995).

3. On December 22, 2000, the court issued its construction of disputed claim terms as follows:

a. "Aluminum alloy sheet product." As understood by one of ordinary skill in the art, an aluminum product with a maximum thickness of 1/4 inches.

b. "Aluminum alloy sheet or plate product" and "aluminum alloy product." An aluminum product with a maximum thickness of 5/8 inches.

c. "Clad" and "cladding." Structures containing an outer layer that provides protection against corrosion. Claims without reference to "clad" or "cladding" apply to both clad and unclad products.

d. "Minimum" and "maximum." A level referring to guaranteeable property values established by repeated testing of many pieces of metal to establish consistent, uniform values.

e. "Long transverse yield strength." As understood by one of ordinary skill in the art, the stress, applied across the width of a product, that a product can sustain before yielding or breaking.

f. “Fracture toughness.” Consistent with the understanding of one of ordinary skill in the art, resistance to extension of a crack, often measured in terms of the stress-intensity factor (K) at which applying progressively greater stress to a structure that contains a pre-existing crack causes the onset of rapid catastrophic propagation of that crack.

g. “Fatigue crack growth rate.” Consistent with the understanding of one of ordinary skill in the art, the rate of crack extension caused by cycles of stressing and relaxing, expressed in terms of average crack extension per cycle (da/dN).

h. “One or more of the levels shown in FIG. 8 or 9.” Refers to a product on which a test at any single)K level results in a fatigue crack growth rate (da/dN) value with the required relationship to that level for da/dN shown in FIG. 8 or 9.

i. The preamble terms “aircraft,” “aircraft skin,” “fuselage skin,” “aircraft fuselage skin,” “aircraft fuselage, or fuselage portion” and “an aircraft having” “a member,” “skin material” or “a fuselage skin” limit the claims in which they appear to the specific use described by those terms.

j. All of the ‘639 patent claims at issue are limited to products that are formable and resistant to corrosion.

4. The court concludes that Alcoa has demonstrated by a preponderance of the evidence that 2024A infringes the asserted

claims of the '639 patent. Testimony by party witnesses, Pechiney's Qualification Report and Professor Hertzberg's analysis confirm that the thickness, composition and guaranteeable properties of 2024A fall within the limits of the asserted claims, and that 2024A is formable, corrosion resistant and suitable for use in aircraft applications. Pechiney rebuts this evidence only by arguing that 2024A cannot infringe the asserted claims because it embodies the prior art. This raises the separate question of validity, however, and does not affect the analysis of whether "every limitation set forth in a claim must be found in an accused product, exactly." Southwall Tech., 54 F.3d at 1575.

B. Invalidity By Obviousness

5. Pechiney contends that the asserted claims of the '639 patent are invalid as obvious under 35 U.S.C. § 103(a).

6. To establish that a patent claim is obvious, it must be shown by clear and convincing evidence, that "the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art." 35 U.S.C. § 103(a). The question of obviousness turns on four factual inquiries: (1) the scope and content of the prior art; (2) the level of ordinary skill in the art; (3) the differences between the claimed invention and the prior art; and (4) any objective indicators of non-obviousness, such as commercial success. See

Graham v. John Deere Co., 383 U.S. 1, 17-18 (1966); B.F. Goodrich Co. v. Aircraft Braking Sys. Corp., 72 F.3d 1577, 1582 (Fed. Cir. 1996).

7. The existence of each limitation of a claim in the prior art does not, by itself, demonstrate obviousness. Instead, there must be a "reason, suggestion, or motivation in the prior art that would lead one of ordinary skill in the art to combine the references, and that would also suggest a reasonable likelihood of success." Smiths Indus. Med. Sys., Inc. v. Vital Signs, Inc., 183 F.3d 1347, 1353 (Fed. Cir. 1999). "Such a suggestion or motivation may come from the references themselves, from knowledge by those skilled in the art that certain references are of special interest in a field, or even from the nature of the problem to be solved." Id. at 1356.

8. "The burden of showing, by clear and convincing evidence, the invalidity of patent claims is especially difficult when the prior art was before the PTO examiner during the prosecution of the application." Hewlett-Packard Co. v. Bausch & Lomb, Inc., 909 F.2d 1464, 1467 (Fed. Cir. 1990).

9. "Objective evidence of non-obviousness may be used to rebut a prima facie case of obviousness based on prior art references." Tec Air, Inc. v. Denso Mfg. Mich, Inc., 192 F.3d 1353, 1360 (Fed. Cir. 1999). In determining whether an invention is non-obvious, there are at least nine objective factors, i.e.,

"secondary considerations" that may be considered: (1) a long-felt and unmet need in the art for the invention; (2) failure of others to achieve the results of the invention; (3) commercial success of the invention; (4) copying of the invention by others in the field; (5) whether the invention was contrary to accepted wisdom of the prior art; (6) expression of disbelief or skepticism by those skilled in the art upon learning of the invention; (7) unexpected results; (8) praise of the invention by those in the field; and (9) independent invention by others. See Graham, 383 U.S. at 17-19; Ruiz v. A.B. Chance Co., 234 F.3d 654, 667-68 (Fed. Cir. 2000).

10. The parties agree that one of ordinary skill in the art is a trained aluminum metallurgist with experience in aerospace applications. (D.I. 423 at 1498; D.I. 424 at 1793)

11. The court concludes that Pechiney has failed to prove by clear and convincing evidence that the asserted claims are invalid for obviousness. Although certain aspects of the claimed invention appear in individual prior art references, Pechiney has not shown sufficient reason, suggestion or motivation to lead one of ordinary skill in the art to combine those aspects so as to render the claimed invention obvious. Furthermore, several secondary considerations support a finding of non-obviousness, including: Boeing's desire to develop a new high-strength, damage-tolerant alloy in the face of several aircraft failures;

Alcoa’s and Pechiney’s prior unsuccessful attempts to develop an improved alloy; the inventors’ surprise at the rifle shot results; Dr. Chakrabarti’s doubts about using a high-temperature reheat process to improve damage tolerance; and the commercial success of the 2524 alloy.

C. Invalidity By Anticipation Under the On-Sale Bar

12. Pechiney contends that the asserted claims of the ‘639 patent are invalid as anticipated under the on-sale bar of 35 U.S.C. § 102(b) based on: (1) Alcoa’s sales of C188 samples to Boeing; (2) Mr. Wright’s January 29, 1990 letter to Boeing; and (3) the Millenium proposal.

1. Applicable Legal Standards

13. Section 102(b) provides, in pertinent part:

> A person shall be entitled to a patent unless . . . the invention was . . . on sale in this country, more than one year prior to the date of the application for patent in the United States.

35 U.S.C. § 102(b). A determination that a patented product was placed on sale more than one year before the filing date of the patent application is a conclusion of law based on underlying findings of fact. See Monon Corp. v. Stoughton Trailers, Inc., 239 F.3d 1253, 1257 (Fed. Cir. 2001). The date one year prior to the date on which the patent application was filed is known as the “critical date.” See id. To prevail on a claim of invalidity based on the on-sale bar, an accused infringer must

demonstrate by clear and convincing evidence that the patented device was both the subject of a commercial offer for sale and ready for patenting before the critical date. See Pfaff v. Wells Elecs., Inc., 525 U.S. 55, 67 (1998); Monon Corp., 239 F.3d at 1257. See also Robotic Vision Sys., Inc. v. View Eng'g, Inc., 249 F.3d 1307, 1313 (Fed. Cir. 2001) (holding that on-sale bar triggered by prior commercial offer for sale and subsequent enabling disclosure that demonstrated invention was ready for patenting prior to critical date).

14. The parties agree that the critical date for the '639 patent is March 6, 1991. (D.I. 425 at 2063)

a. Commercial Offer for Sale of the Patented Invention

15. The first element of the on-sale bar requires that the invention be the subject of a commercial sale or offer for sale. This element contains two sub-parts. The court must find that there was both a "commercial offer" and that the offer was for the patented invention. See Scaltech, Inc. v. Retec/Tetra, L.L.C., 269 F.3d 1321, 1328 (Fed. Cir. 2001).

1) Commercial Offer for Sale

16. "[T]he question of whether an invention is the subject of a commercial offer for sale is a matter of Federal Circuit law, to be analyzed under the law of contracts as generally understood." Group One, Ltd. v. Hallmark Cards, Inc., 254 F.3d 1041, 1047 (Fed. Cir. 2001), cert. denied, 122 S.Ct. 1063 (2002).

"Only an offer which rises to the level of a commercial offer for sale, one which the other party could make into a binding contract by simple acceptance (assuming consideration), constitutes an offer for sale under § 102(b)." Id. at 1048. Courts should look to the "substantial body of general contract law" to determine whether a commercial offer to sell the claimed invention has been made. Id. at 1047-48.

17. "An offer is the manifestation of willingness to enter into a bargain, so made as to justify another person in understanding that his assent to that bargain is invited and will conclude it." Linear Tech. Corp. v. Micrel, Inc., 275 F.3d 1040, 1050 (Fed. Cir. 2001), petition for cert. filed, 71 U.S.L.W. 3039 (U.S. Jul. 3, 2002) (No. 02-39) (quoting Restatement (Second) of Contracts § 24 (1981)). "A manifestation of willingness to enter into a bargain is not an offer if the person to whom it is addressed knows or has reason to know that the person making it does not intend to conclude a bargain until he has made a further manifestation of assent." Linear Tech., 275 F.3d at 1050 (quoting Restatement (Second) of Contracts § 26 (1981)).

18. "In any given circumstance, who is the offeror, and what constitutes a definite offer, requires looking closely at the language of the proposal itself. Language suggesting a legal offer, such as 'I offer' or 'I promise' can be contrasted with language suggesting more preliminary negotiations, such as 'I

quote' or 'are you interested.' Differing phrases are evidence of differing intent, but no one phrase is necessarily controlling." Group One, 254 F.3d at 1048 (citing Restatement (Second) of Contracts §§ 24, 26 (1981)). Factors to consider include: (a) the ordinary meaning of the language; (b) the context of any prior communications between the parties; (c) whether the communication was private or to the general public; (d) any previous course of dealings between the parties; (e) local usage or usage of the trade; (f) the relative completeness of the terms (the more complete, the more likely it is an offer); (g) the subject matter of the offer; and (h) whether it is foreseeable that the recipient would rely upon it. See Joseph M. Perillo, Corbin on Contracts § 2.2 at 109-10 (Rev. ed. 1993).

19. Generally, mere price quotations without other contractual terms (time and place of delivery, terms of payment, etc.) do not constitute offers. See id., § 2.5 at 123; see also Restatement (Second) of Contracts § 26, comment c. Nevertheless, if the quotation comes in reply to a specific request for an offer, contains language of commitment, or comes after prolonged negotiations, and the quotation contains detailed terms, it may be deemed an offer. See Corbin § 2.5, at 126. An estimate is not considered to be an offer or a quotation. See id. However, a bid made in response to an invitation for bids is considered to be an offer. See Richard A. Lord, Williston on Contracts § 4:10

at 338-9 (4th ed. 1990); Restatement (Second) of Contracts § 28, comment c.

20. Advertisements, catalogs, and other promotional materials are generally considered invitations to solicit offers or enter into a bargain, not offers themselves. See Williston § 4:7 at 286-87; see also Restatement (Second) of Contracts § 26, comment b; Group One, 254 F.3d at 1048 ("[M]ere advertising and promoting of a product may be nothing more than an invitation for offers, while responding to such an invitation may itself be an offer"); Linear Tech., 275 F.3d at 1050 (finding that activities in preparation to sell, such as publication of preliminary data sheets and promotional information, do not communicate an intent to sell and thus, by themselves, cannot be offers to sell). Even a published price list is not considered to be an offer to sell goods at the published prices. See Williston § 4:7 at 288; Restatement (Second) of Contracts § 26, comment b.

21. Courts are generally reluctant to find offers from preliminary statements of intention, but where the property to be sold is accurately defined and the communication states prices and is directed at an individual rather than the public in general, it is more reasonable to interpret the communication as an offer to sell at that price. See Williston § 4:7, at 293.

22. An offer for sale need not be accepted to implicate the on-sale bar. See Scaltech, 269 F.3d at 1328. Nor is it relevant

that there was the possibility that the offer, even if accepted, might not ultimately have led to an actual sale of the invention. See id. at 1329.

23. The experimental use doctrine permits an inventor to conduct testing to refine his invention without losing the right to obtain a patent, even if such testing occurs in the public eye. See Pfaff, 525 U.S. at 64 ("The law has long recognized the distinction between inventions put to experimental use and products sold commercially."). The doctrine serves to negate the statutory bar of § 102(b), thus, maintaining the burden of persuasion on the party challenging validity. See Monon Corp., 239 F.3d at 1258; TP Labs., Inc. v. Prof'l Positioners, Inc., 724 F.2d 965, 971 (Fed. Cir. 1984).

24. The experimental use doctrine applies when the transaction constituting the sale was "incidental to the primary purpose of experimentation." Scaltech, Inc. v. Retec/Tetra, L.L.C., 178 F.3d 1378, 1384 n.1 (Fed. Cir. 1999). See also EZ Dock, Inc. v. Schafer Systems, Inc., 276 F.3d 1347, 1352 (Fed. Cir. 2002) (Linn, J., concurring) (stating that a sale is not commercial when "the primary purpose of the inventor at the time of the sale, as determined from an objective evaluation of the facts surrounding the transaction, was to conduct experimentation").

25. "Experimentation evidence includes tests needed to convince the inventor that the invention is capable of performing its intended purpose in its intended environment." EZ Dock, 276 F.3d at 1352 (quotations omitted). In distinguishing commercial from experimental sales, the court must consider a variety of factors, including: (a) the necessity for public testing; (b) the amount of control over the experiment retained by the inventor; (c) the nature of the invention; (d) the length of the test period; (e) whether payment was made; (f) whether there was a secrecy obligation; (g) whether records of the experiment were kept; (h) who conducted the experiment; (i) the degree of commercial exploitation during testing; (j) whether the invention reasonably requires evaluation under actual conditions of use; (k) whether testing was systematically performed; (l) whether the inventor continually monitored the invention during testing; and (m) the nature of contacts made with potential customers. See EZ Dock, 276 F.3d at 1357 (Linn, J., concurring) (citations omitted).

26. Whether payment is made for the device is an important factual consideration, but the fact that a company paid for the use of a patentee's device is not dispositive. See Monon Corp., 239 F.3d at 1260.

27. Furthermore, "[w]hen an inventor can show changes during experimentation that result in features later claimed in

the patent application, this evidence is a strong indication that the activities of the inventor negated any evidence of premature commercial exploitation of an invention ready for patenting." EZ Dock, 276 F.3d at 1353.

28. However, "a use cannot be experimental if the inventor failed to maintain sufficient control over the invention and its testing." Lough v. Brunswick Corp., 103 F.3d 1517, 1526 (Fed. Cir. 1997).

29. Once the invention is reduced to practice, there can be no experimental use negation. See Zacharin v. United States, 213 F.3d 1366, 1369 (Fed. Cir. 2000).

2) Product Offered for Sale was an Embodiment of the Patented Invention

30. The product that is the subject matter of the offer for sale must satisfy each limitation of the asserted claims, though it may do so inherently. See Scaltech, 269 F.3d at 1329. Inherency is established if "the natural result flowing from the operation as taught would result in the performance of the questioned function." Id. (quotation omitted).

31. There is no requirement that the offer specifically identify the claim limitations, nor it is relevant that the inventor may not have recognized the limitations present in the product at the time of the offer. See id. at 1383-84.

b. Ready for Patenting

32. The ready for patenting element of the on-sale bar "may be satisfied in at least two ways: by proof of reduction to practice before the critical date; or by proof that prior to the critical date the inventor had prepared drawings or other descriptions of the invention that were sufficiently specific to enable a person skilled in the art to practice the invention." Pfaff, 525 U.S. at 67-68.

1) Reduction to Practice

33. "[R]eduction to practice involves proof that an invention will work for its intended purpose." EZ Dock, 276 F.3d at 1352.

34. "A process is reduced to practice when it is successfully performed. A machine is reduced to practice when it is assembled, adjusted and used. A manufacture is reduced to practice when it is completely manufactured. A composition of matter is reduced to practice when it is completely composed." See Pfaff, 525 U.S. at 57, n.2.

35. "[W]here an invention is on sale, conception is not required to establish reduction to practice." Scaltech, 269 F.3d at 1331.

2) Enabling Drawings or Descriptions

36. To be enabling, a drawing or description "must teach those skilled in the art how to make and use the full scope of the claimed invention without 'undue experimentation'". Genentech, Inc. v. Novo Nordisk, 108 F.3d 1361, 1365 (Fed. Cir. 1997). See also Robotic Vision Sys., 249 F.3d at 1312 (stating that invention is ready for patenting when "the disclosure of the invention was made prior to the critical date and was sufficiently specific to enable a person skilled in the art to practice the invention.").

2. Application of the Law to the Facts

37. The court concludes that Pechiney has failed to prove by clear and convincing evidence that Alcoa's sales of C188 samples to Boeing, Mr. Wright's January 1990 letter, or the Millenium proposal render the asserted claims invalid as anticipated under the on-sale bar.

38. First, none of the above constitutes a "commercial offer for sale of the patented invention." The sale of C188 samples was experimental, not commercial, as evidenced by the "XBMS" designation on the sales orders, destructive testing conducted by Boeing on the samples, and sharing of the test results. Mr. Wright's letter and the Millenium proposal do not contain sufficient specific terms (quantity, time and place of delivery) to warrant consideration as commercial offers for sale.

Rather, these proposals are merely invitations for further discussion between Alcoa and Boeing.

39. Regardless of whether the sale of C188 samples, Mr. Wright's letter or the Millenium proposal constitute commercial offers for sale, the court finds that the claimed invention was not ready for patenting before the critical date of March 6, 1991. Alcoa's design allowables testing and Boeing's round robin tests, both of which generated fatigue crack growth rate and guaranteeability data incorporated into the CIP application, continued into late 1991 and early 1992. Because this data led to a fundamental characteristic of the claimed invention, the invention could not have been reduced to practice or described without undue experimentation until the completion of the design allowables and round robin tests, which occurred after the critical date.

E. Unenforceability

40. Pechiney contends that the '639 patent is unenforceable because the applicants intentionally withheld material information during prosecution regarding 2124 and 2024 alloy products and processes, and Alcoa's commercialization of the claimed invention prior to the critical date.

41. "Applicants for patents are required to prosecute patent applications in the PTO with candor, good faith, and honesty." Molins PLC v. Textron, Inc., 48 F.3d 1172, 1178 (Fed.

Cir. 1995). The duty to prosecute patent applications with candor, good faith, and honesty "rests on the inventor, on each attorney or agent who prepares or prosecutes an application and on every other individual who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee, or with anyone to whom there is an obligation to assign the application." Id. at 1178 n.6.

42. "The duty of candor extends throughout the patent's entire prosecution history. In determining inequitable conduct, a trial court may look beyond the final claims to their antecedents. 'Claims are not born, and do not live, in isolation. Each is related to other claims, to the specification and drawings . . . [and] to earlier or later versions of itself in light of amendments made to it.' . . . Therefore, a breach of the duty of candor early in the prosecution may render unenforceable all claims which eventually issue from the same or a related application." Fox Indus., Inc. v. Structural Preservation Sys., Inc., 922 F.2d 801, 803-04 (Fed. Cir. 1991).

43. A charge of inequitable conduct includes within its scope "affirmative misrepresentation of a material fact, failure to disclose material information, coupled with an intent to deceive." Molins PLC, 48 F.3d at 1178.

44. "A holding of inequitable conduct requires proof by clear and convincing evidence. This proof must include a threshold showing of both materiality and intent to mislead or deceive the patent examiner." Monon Corp., 239 F.3d at 1261 (citing Manville Sales Corp. v. Paramount Sys., Inc., 917 F.2d 544, 551 (Fed. Cir. 1990)).

45. The governing standard for materiality is the one in place when the pertinent events of the patent prosecution occurred. See CFMT, Inc. v. YieldUP Int'l Corp., 144 F. Supp.2d 305, 316 (D. Del. 2001). Prior to March 16, 1992, "materiality" was defined as whether there was a "substantial likelihood that a reasonable examiner would have considered the information important in deciding whether to allow the application to issue as a patent."[25] Molins PLC, 48 F.3d at 1179. A reference was not considered material if it was not as relevant as that actually considered by the examiner or if it was merely cumulative of the information considered by the examiner. See id. On March 16, 1992, an amended PTO Rule 56 went into effect, applying to all applications and reexamination proceedings pending or filed after that date. Rule 56 provides:

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[25]"Information concealed from the PTO may be material even though it would not invalidate the patent. . . . As stated, the test for materiality is whether a reasonable examiner would have considered the information important, not whether the information would conclusively decide the issue of patentability." Li Second Family Ltd. P'ship, 231 F.3d 1373, 1383 (Fed. Cir. 2000), cert. denied, 533 U.S. 929 (2001).

> [I]nformation is material to patentability when it is not cumulative to information already of record or being made of record in the application, and
>
> > (1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or
> >
> > (2) It refutes, or is inconsistent with, a position the applicant takes in:
> >
> > > (i) Opposing an argument of unpatentability relied on by the Office, or
> > >
> > > (ii) Asserting an argument of patentability.
>
> A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

37 C.F.R. § 1.56(b).

46. "Intent" commonly means "a state of mind in which a person seeks to accomplish a given result through a course of action." Molins PLC, 48 F.3d at 1180 (citing Black's Law Dictionary at 810 (6th ed. 1990)). "Intent need not be proven by direct evidence; it is most often proven by a showing of acts, the natural consequences of which are presumably intended by the actor." Id. "For example, intent may be inferred where a patent

applicant knew, or should have known, that withheld information would be material to the PTO's consideration of the patent application." Critikon, Inc. v. Becton Dickinson Vascular Access, Inc., 120 F.3d 1253, 1256 (Fed. Cir. 1997).

47. "If the threshold requirements of materiality and intent are established, 'those fact findings are balanced to make the determination whether the scales tilt to a conclusion that inequitable conduct occurred.' . . . 'The more material the omission or the misrepresentation, the lower the level of intent required to establish inequitable conduct, and visa versa.' . . . If, however, either materiality or intent is not found, then no further analysis need be performed and unenforceability must be denied.'" Monon Corp., 239 F.3d at 1261 (citations omitted).

48. "It is not inequitable conduct to omit telling the patent examiner information that the applicant in good faith believes is not material to patentability." Allied Colloids, Inc. v. Am. Cyanamid Co., 64 F.3d 1570, 1578 (Fed. Cir. 1995). Disclosure of relevant prior art to the PTO during the course of another, subsequent patent prosecution "has no bearing on whether [the patentee] acted with deceptive intent during prosecution of the" application at issue. Li Second Family Ltd. P'ship, 231 F.3d at 1381.

49. "Because the adjudication of an inequitable conduct claim is an equitable determination, it is committed to the discretion of the trial court." Monon Corp., 239 F.3d at 1261.

50. The court concludes that Pechiney has not carried its burden of proving by clear and convincing evidence that the applicants intended to deceive the PTO concerning a material fact during the prosecution of the '639 patent.[26] The 417 Process, including a reset step and solution heat treatment step designed for plate products, teaches away from the '639 patent. Under either standard of materiality, the court finds that the 417 Process cannot be considered material because it contains features that contradict the claimed invention. The other 2124 references are immaterial because they are cumulative of the Hyatt patent, which was considered by the patent examiner. The allegedly "commercial" sales are immaterial because the court has determined that they are not invalidating and the applicants reasonably believed them to be permissible sales during prosecution. Furthermore, no intent of deception or bad faith is apparent from the record. Therefore, the threshold levels of materiality and intent have not been demonstrated by clear and convincing evidence. Even had the threshold levels of materiality and intent been demonstrated by clear and convincing

[26]The parties have agreed that Pechiney may rely on all of the claims of the '639 patent (asserted and unasserted) to sustain its claim of inequitable conduct.

evidence, it is the court’s equitable judgment that the applicants’ conduct was not so culpable that the ‘639 patent should not be enforced.

IV. CONCLUSION

For the reasons stated, Pechiney’s 2024A alloy infringes the asserted claims of Alcoa’s ‘639 patent. The asserted claims are not invalid by obviousness, and not invalid by anticipation under the on-sale bar. The ‘639 patent is enforceable. An appropriate order shall issue and judgment shall be entered accordingly.